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Study of Seismic Performance for Open Ground Storey of High Rise Buildings

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ABSTRACT: Open Ground Storey (OGS) means ground storey not having walls. Now a days, OGS is a typical feature in multi-storied building construction in order to provide facilities like car parking, restaurants, bank branches, reception lobbies, offices, etc., but this causes soft storey effect. A soft storey is characterized by vertical discontinuity in stiffness. When an individual storey in a building is made taller and/or more open in construction, it is called soft storey or flexible storey. Stiffness is to resist lateral displacement. The main aim of this project is to study seismic response of multi storey building after providing frustum of cone shaped column at ground storey. In this study a comparative analysis between typical rectangular shaped column & frustum of cone shaped column at open ground storey of multi storeyed building is done using ETABS. G+19, G+15 & G+11 building is modelled as bare frame & then considering infilled wall as equivalent diagonal strut. After analyzing the model using ETABS, storey stiffness is compared between typical shaped column & frustum of cone shaped column at open ground storey.

KEYWORDS: Storey stiffness, OGS, Soft storey, Frustum of cone shaped column, Response spectrum, ETABS

I. INTRODUCTION

A soft storey is characterized by vertical discontinuity in stiffness. When an individual storey in a building is made taller and/or more open in construction, it is called soft storey or flexible storey. The soft storey can occur at an upper level but it is more common at the ground level between a rigid foundation system and a relatively stiffer upper level floor system. Any storey for which the lateral stiffness is less than 60% of that of the storey immediately above, or less than 70% of the combined stiffness of the three storeys above, is classified as soft storey. Stiffness is to resist lateral displacement.

A building has the potential to 'wave' back and forth during an earthquake (or even a severe wind storm). This is called the 'fundamental mode', and is the lowest frequency of building response. Most buildings, however, have higher modes of response, which are uniquely activated during earthquakes. Nevertheless, the first and second modes tend to cause the most damage in most cases. Structural analysis methods can be divided into:

(1)Equivalent Static Analysis: This approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. For this to be true, the building must be low-rise and must not twist significantly when the ground moves. The response is read from a design response spectrum, given the natural frequency of the building (either calculated or defined by the building code). To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces (e.g. force reduction factors).

(2)Response Spectrum Analysis: This approach permits the multiple modes of response of a building to be taken into account (in the frequency domain). The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the "harmonics". Computer analysis can be used to determine these modes for a structure. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass, and they are then combined to provide an estimate of the total response of the structure. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building. Combination methods include the following:

1. Absolute – peak values are added together
2. Square Root Of The Sum Of The Squares (SRSS)
3. Complete Quadratic Combination (CQC) – it is an improvement on SRSS for closely spaced modes.

II. RELATED WORK

Amit kumar, Mohd. Adnan(2019), “Earthquake Resistance Design of Open Ground Storey Building”, IRJET performed Push over non- linear static analysis of the different height of the buildings with open ground storey. Using SAP2000, they made six models, G+8, G+10 & G+12 with equivalent diagonal strut of infilled wall & G+8, G+10 & G+12 without equivalent diagonal strut. According to results, the time period, lateral displacement and storey drift in x-direction of without equivalent strut is greater than the equivalent strut. Also, as per ISCODE 1893-2016 PART-1 provisions standard value which is not exceed 0.004 times of (h) is higher in structure without strut and value is low in with equivalent strut.

Nilesh Patil, Aniket chougule, Harshavardhan Patil, Umesh Shinde, Vivek Pawar, Prof. Rushank Patil(2019), “Earthquake Analysis of RC Building With and Without Infill Wall”, IRJET performed seismic analysis of multi storey building and compared Base Shear, Joint Displacement, Storey drift, Mass Participation. And concluded that (1) The results as obtained using STAAD.Pro for with and without infill walls are compared for different categories of a beams shows a difference between with and without infill walls where without infill walls show the maximum values. (2)The difference in storey drift is 50% higher for without infill than with infill walls.

Vihar S. Desai, Hitesh K. Dhameliya, Yati R. Tank(2017), “Seismic Behavior of RC Framed Building with Soft Storey”, IJERT studied performance of a building with soft storey (G+14) at different level along with ground level. Also it has been tried to investigate on adding of shear wall to structures in order to reduce soft storey effect on seismic response of building. Following conclusion was made, (1)As the level of the soft storey increase the value of displacement decrease. (2)As the level of the soft storey decrease the value of drift and time period increase. (3)The storey shear is maximum at ground level and keeps on decreasing towards the top storey of the structure.

Piyush Tiwari, P.J.Salunke, N.G.Gore(2015), "Earthquake Resistant Design of Open Ground Storey Building", IRJET (1) studied the applicability of the Multiplication Factor of 2.5 as given by IS Code 1893 Part-1(2002), for Low Rise and Medium Rise Open ground storey Building. And concluded that (1) Linear(Static/Dynamic) analysis shows that column forces at the ground storey increase for the presence of infill wall in upper storeys. But design force Multiplication factor found to be much less than 2.5.

III. METHODOLOGY

Modelling of G+19, G+15 & G+11 bare frame as well as infilled frame as equivalent diagonal strut with open ground storey building in ETABS. Typical rectangular shaped column is then replaced with frustum of cone shaped column at open ground storey. Seismic analysis (static as well as dynamic) is done as per IS 1893-2016 using ETABS. Storey stiffness at each floor of each model is compared. Obtaining other seismic parameters like base shear, base moment, torsion & max displacement.

IV. STRUCTURAL MODELLING

In this study, structure will be modelled for the following 12 cases:

1. Typical shaped column
 - (a) G+19 Bare frame (b) G+19 Infilled frame (c) G+15 Bare frame (d) G+15 Infilled frame (e) G+11 Bare frame (f) G+11 Infilled frame
2. Frustum of cone shaped column at ground floor.
 - (g) G+19 Bare frame (h) G+19 Infilled frame (i) G+15 Bare frame (j) G+15 Infilled frame (k) G+11 Bare frame (l) G+11 Infilled frame

V. PRELIMINARY DATA

1.Length in X direction=20 m, 2.Length in Y direction= 12.5 m, 3.Typical storey height=2.9 m, 4.Ground storey height=4.2 m, 5.No. of storey =G+19 (a)Height of building =59.3 m (b)Beam size: 300 x 600 mm (c)Column size: 300 x 900 mm (d)Frustum of cone shaped column size: above dia: 900 mm & below dia: 1300 mm

6.No. of storey =G+15 (a)Height of building =47.7 m (b)Beam size: 300 x 550 mm (c) Column size: 300 x 800 mm (d)Frustum of cone shaped column size: above dia: 800 mm & below dia: 1200 mm

7.No. of storey =G+11 (a)Height of building =36.1 m (b)Beam size: 300 x 500 mm (c)Column size: 300 x 700 mm (d)Frustum of cone shaped column size: above dia: 700 mm & below dia: 1100 mm

Load Calculation:

Dead load: self-weight of the member (by ETABS), Floor finish= 0.5 kN/m², External wall load=0.23*2.3*6= 3.2 kN/m, Internal wall load=0.1*2.3*6= 1.4 kN/m, live load= 3 kN/m², seismic loading, Z=0.16 (for zone iii, IS1893:2016), I=1.2

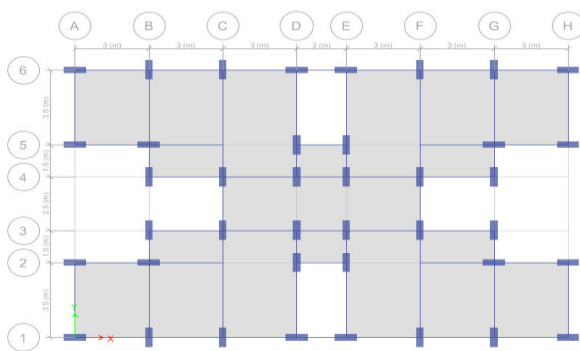


Fig.1: Plan- Typical rectangular shaped column
(Source: ETABS)

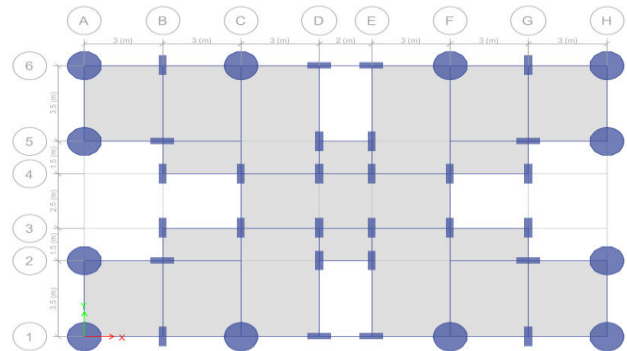


Fig.2: Plan- Frustum of cone shaped column at ground storey
(Source: ETABS)

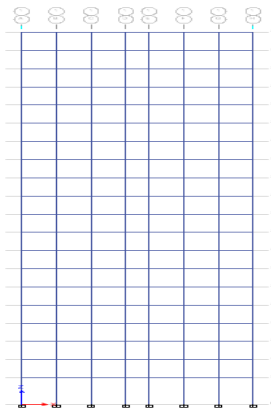


Fig.3: Elevation- Bare frame
(Source: ETABS)

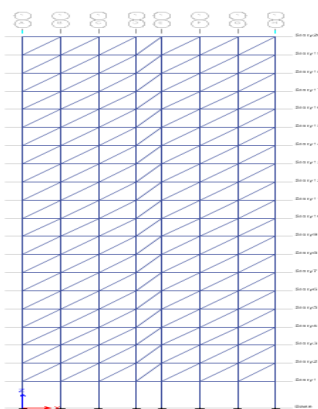


Fig.4: Elevation- Infilled frame
(Source: ETABS)

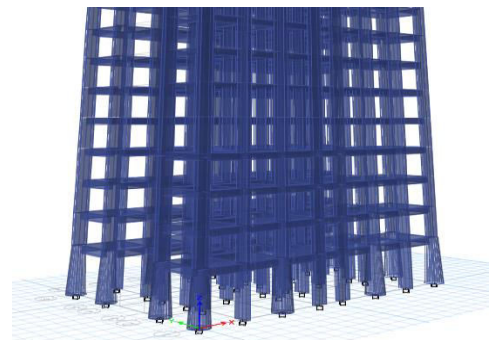


Fig.5: 3D – Frustum of cone shaped column
(Source: ETABS)

VI. EXPERIMENTAL RESULTS

Storey stiffness curve X-axis			
Stories	G+19	G+15	G+11
Storey20	10%		
Storey19	8%		
Storey18	7%		
Storey17	6%		
Storey16	5%	13%	
Storey15	5%	10%	
Storey14	4%	7%	
Storey13	4%	6%	
Storey12	4%	5%	13%
Storey11	4%	5%	9%
Storey10	4%	5%	7%
Storey9	5%	4%	6%
Storey8	5%	4%	5%
Storey7	5%	4%	4%
Storey6	5%	5%	4%
Storey5	5%	5%	4%
Storey4	6%	5%	4%
Storey3	7%	6%	4%
Storey2	22%	19%	16%
Storey1	142%	129%	123%

Table1.1: Storey stiffness curve (X-axis)

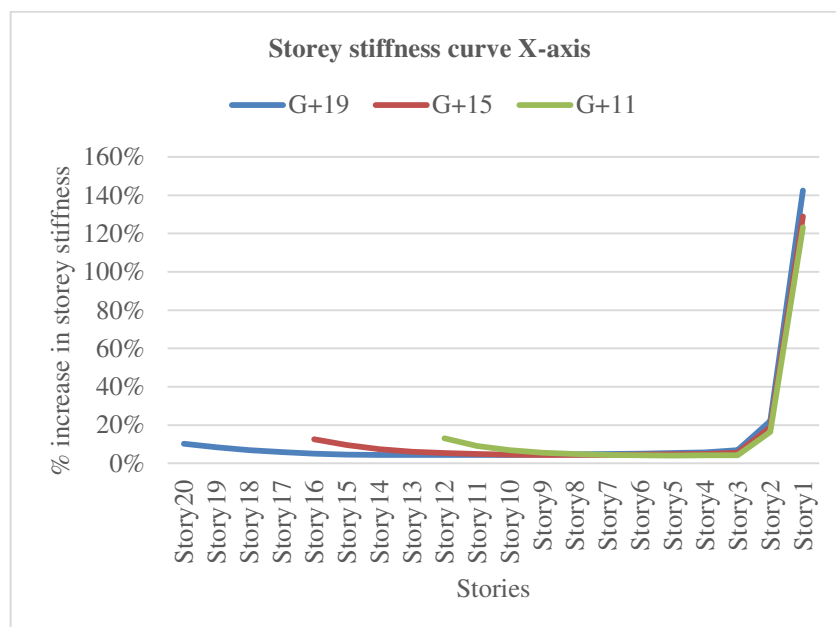


Fig.6.1: Storey stiffness curve (X-axis)

Storey stiffness curve Y-axis			
Stories	G+19	G+15	G+11
Storey20	7%		
Storey19	6%		
Storey18	5%		
Storey17	4%		
Storey16	3%	8%	
Storey15	3%	6%	
Storey14	3%	5%	
Storey13	3%	4%	
Storey12	4%	4%	10%
Storey11	4%	4%	8%
Storey10	4%	4%	7%
Storey9	5%	5%	6%
Storey8	5%	5%	6%
Storey7	6%	6%	6%
Storey6	7%	7%	7%
Storey5	8%	8%	8%
Storey4	10%	10%	10%
Storey3	13%	13%	13%
Storey2	26%	25%	25%
Storey1	111%	109%	107%

Table1.2: Storey stiffness curve (Y-axis)

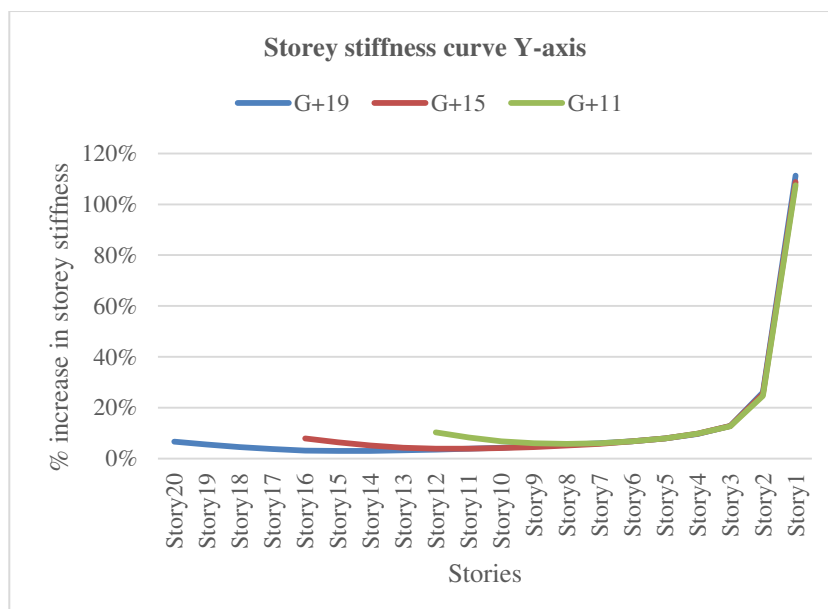


Fig.6.2: Storey stiffness curve (Y-axis)

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Increase in storey stiffness	% increase in storey stiffness
		RSx (kN/m)	RSx (kN/m)	RSx (kN/m)	RSx (kN/m)
Infilled frame building	G+19	976284	2366456	1390172	142%
	G+15	770506	1763019	992513	129%
	G+11	589397	1315440	726043	123%
Bare frame building	G+19	852365	1969885	1117520	131%
	G+15	670941	1506083	835142	124%
	G+11	513569	1120546	606977	118%

Table2.1: Ground Storey stiffness comparison of different building height (X-axis)

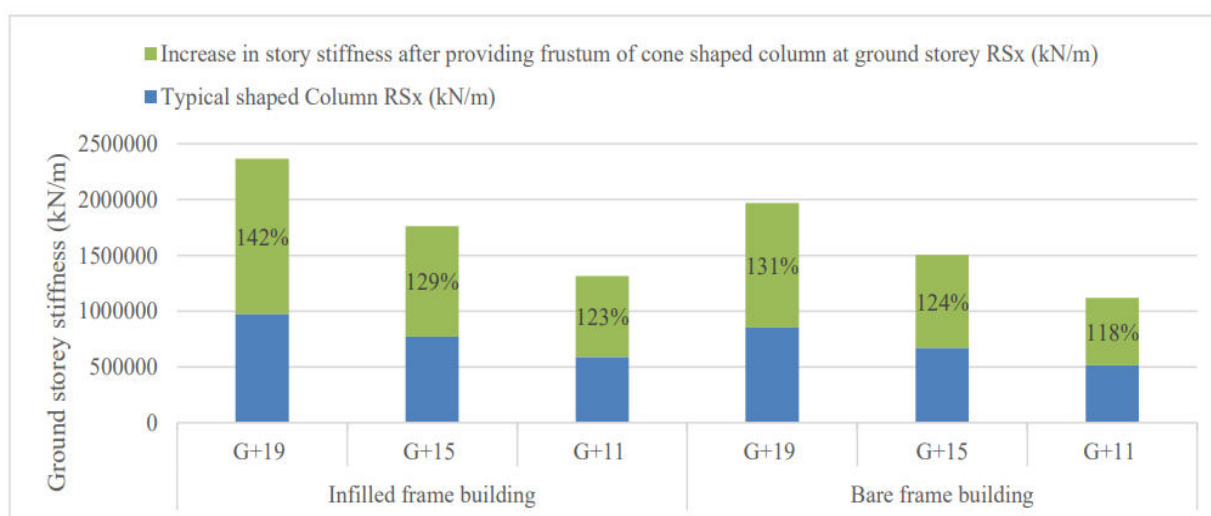


Fig.7.1: Ground Storey stiffness comparison of different building height (X-axis)

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Increase in storey stiffness	% Change in storey stiffness
		Rsy (kN/m)	Rsy (kN/m)	Rsy (kN/m)	Rsy (kN/m)
Infilled frame building	G+19	1157736	2445616	1287880	111%
	G+15	910028	1900149	990121	109%
	G+11	691585	1434633	743048	107%
Bare frame building	G+19	992617	2055596	1062979	107%
	G+15	776857	1585626	808770	104%
	G+11	590357	1193210	602853	102%

Table2.2: Ground Storey stiffness comparison of different building height (Y-axis)

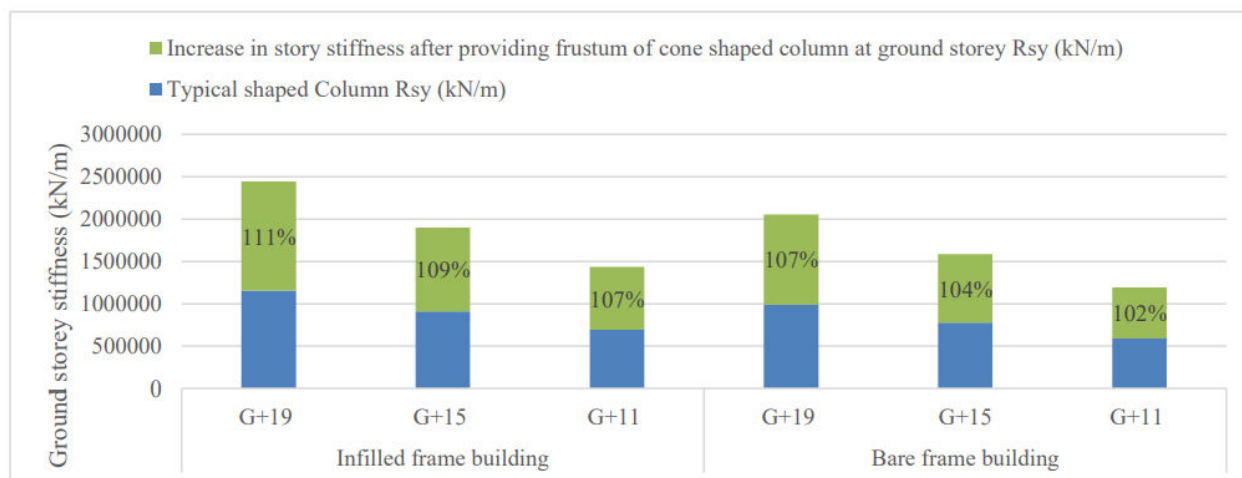


Fig.7.2: Ground Storey stiffness comparison of different building height (Y-axis)

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Change in base shear	% Change in base shear
		V _x (kN)	V _x (kN)	V _x (kN)	V _x (kN)
Infilled frame building	G+19	2183.67	2195.12	11.45	1%
	G+15	2074.30	2087.76	13.46	1%
	G+11	1952.20	1965.23	13.03	1%
Bare frame building	G+19	2010.66	2023.01	12.35	1%
	G+15	1906.55	1919.20	12.64	1%
	G+11	1789.25	1802.74	13.49	1%

Table3.1: Base Shear comparison of different building height (X-axis)

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Change in base shear	% Change in base shear
		V _x (kN)	V _x (kN)	V _x (kN)	V _x (kN)
Infilled frame building	G+19	1727.06	1736.52	9.46	1%
	G+15	1638.73	1648.94	10.21	1%
	G+11	1543.98	1554.06	10.08	1%
Bare frame building	G+19	1590.91	1600.64	9.72	1%
	G+15	1506.02	1516.07	10.05	1%
	G+11	1415.44	1426.11	10.67	1%

Table3.2: Base Shear comparison of different building height (Y-axis)

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Change in torsion	% Change in Torsion
		T (kN-m)	T (kN-m)	T (kN-m)	T (kN-m)
Infilled frame building	G+19	21797.81	21909.02	111.21	1%
	G+15	20659.67	20782.68	123.01	1%
	G+11	19437.64	19554.01	116.37	1%
Bare frame building	G+19	20273.63	20397.79	124.16	1%
	G+15	19204.13	19331.98	127.84	1%
	G+11	18038.92	18174.92	135.99	1%

Table.4: Torsion comparison of different building height

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Change in Base moment	% Change in Base moment
		M _x (kN-m)	M _x (kN-m)	M _x (kN-m)	M _x (kN-m)
Infilled frame building	G+19	59561.03	61142.36	1581.34	3%
	G+15	48485.16	49713.88	1228.72	3%
	G+11	36343.17	37264.53	921.36	3%
Bare frame building	G+19	55663.04	57128.53	1465.50	3%
	G+15	45082.45	46037.72	955.27	2%
	G+11	33336.68	34231.74	895.06	3%

Table5.1: Base Moment comparison of different building height (X-axis)

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Change in Base moment	% Change in Base moment
		M _y (kN-m)	M _y (kN-m)	M _y (kN-m)	M _y (kN-m)
Infilled frame building	G+19	80579.56	82767.07	2187.51	3%
	G+15	62929.23	64877.66	1948.43	3%
	G+11	45039.56	46880.61	1841.05	4%
Bare frame building	G+19	73122.00	74919.03	1797.03	2%
	G+15	57816.86	59102.16	1285.30	2%
	G+11	41983.94	43301.34	1317.40	3%

Table5.2: Base Moment comparison of different building height (Y-axis)

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Change in Max displacement	% Change in Max displacement
		U _x (mm)	U _x (mm)	U _x (mm)	U _x (mm)
Infilled frame building	G+19	42.51	38.66	-3.85	-9%
	G+15	32.54	28.90	-3.64	-11%
	G+11	24.11	20.44	-3.67	-15%
Bare frame building	G+19	58.06	53.99	-4.06	-7%
	G+15	49.17	45.21	-3.96	-8%
	G+11	40.35	36.35	-4.00	-10%

Table6.1: Max displacement comparison of different building height (X-axis)

Building type	Building height	Typical shaped Column	Frustum of cone shaped Column at ground storey	Change in Max displacement	% Change in Max displacement
		U _y (mm)	U _y (mm)	U _y (mm)	U _y (mm)
Infilled frame building	G+19	59.20	55.40	-3.80	-6%
	G+15	44.28	40.71	-3.57	-8%
	G+11	31.08	27.58	-3.50	-11%
Bare frame building	G+19	58.62	55.63	-2.99	-5%
	G+15	46.70	43.89	-2.81	-6%
	G+11	36.00	33.20	-2.80	-8%

Table6.2: Max displacement comparison of different building height (Y-axis)

VII. CONCLUSION

Following are the conclusions obtained from this study:

1. Linear (static/dynamic) analysis shows that the stiffness of each storey increases after providing frustum of cone shaped column at ground storey.
2. Increase in storey stiffness is maximum for ground storey in the range of 105% to 140%, then storey just above increases 15% to 25%, whereas middle stories show 3% to 8% increase and top storey 9% to 13% for different building heights G+19, G+15 & G+11 bare frame as well as infilled frame.
3. G+19, G+15 & G+11 buildings follow almost same curve path of their inter storey stiffness variation along X as well as Y-axis.
4. RSA result for various seismic parameters like storey stiffness, base shear, base moment and torsion show around 5% increment for infilled frame as compared with bare frame of different building heights G+19, G+15 & G+11.
5. Frustum of cone shaped column at ground storey does not affect other seismic parameters significantly. Like base shear and torsion increases by 1% only, whereas, base moment increases by 3% for different building heights G+19, G+15 & G+11.
6. There is a decrease in max displacement value of building, by 5% to 15%, after providing frustum of cone shaped column at ground storey.

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